Auxiliary Systems

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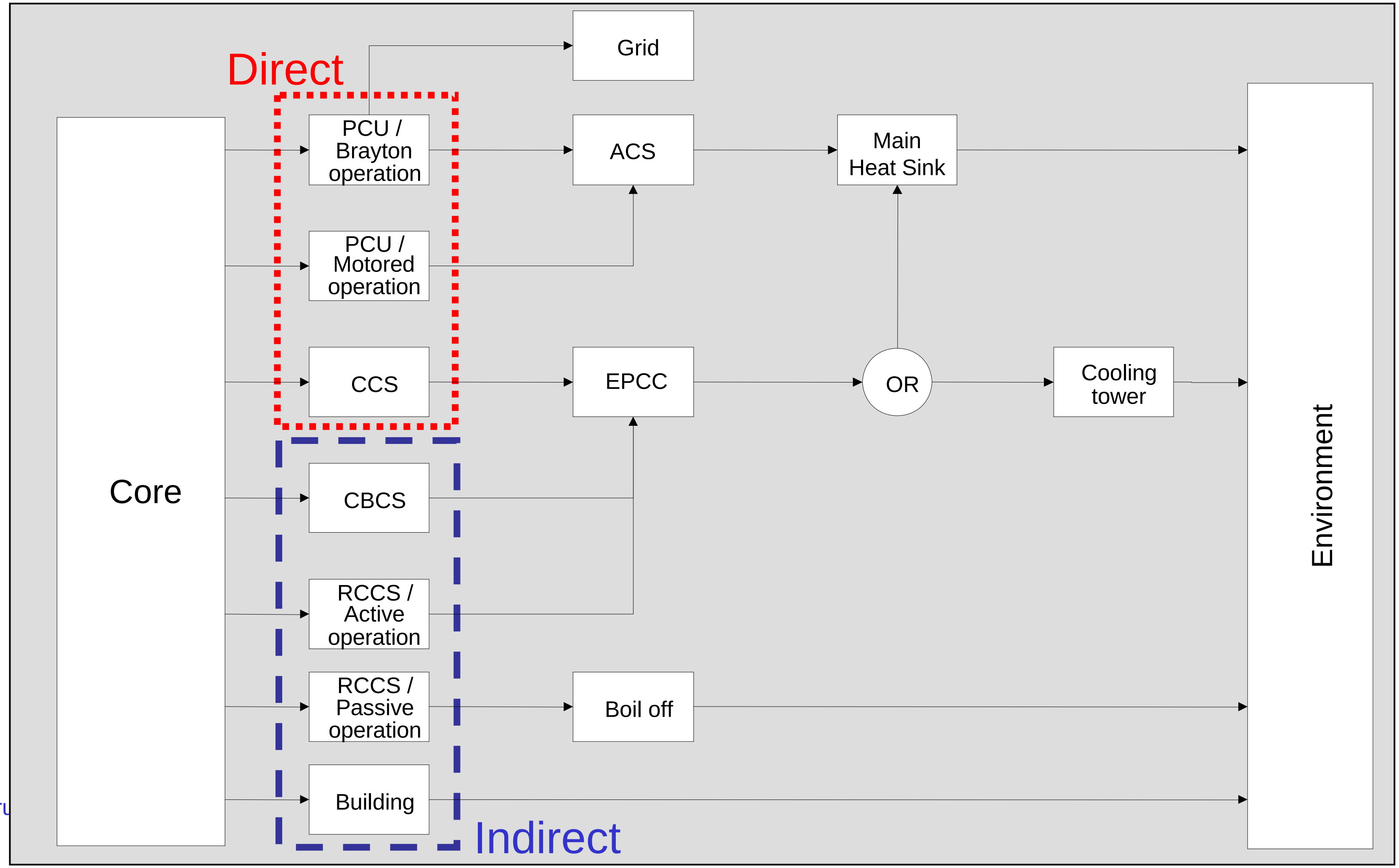
PBMR Auxiliary Systems

- **Cooling Circuits**
  - Main Heat Sink System (MHS)
  - Active Cooling System (ACS)
  - Reactor Cavity Cooling System (RCCS)
  - Equipment Protection Cooling Circuit (EPCC)
- **Pressure Relief System (PRS)**
- **Heating, Ventilation, Air Condition System (HVAC)**
- **Fire Protection System (FPS)**
- **Waste Handling System (WHS)**
- **Additional Auxiliary Systems Not Presented**
  - Primary Loop Initial Cleanup System (PLICS)
  - Compressed Air System (CAS)
  - Decontamination System (DS)
  - Specialized Doorways
  - Special Tools and Equipment Handling Systems

ENERGY REMOVAL PATHS



Main Heat Sink System (MHSS)

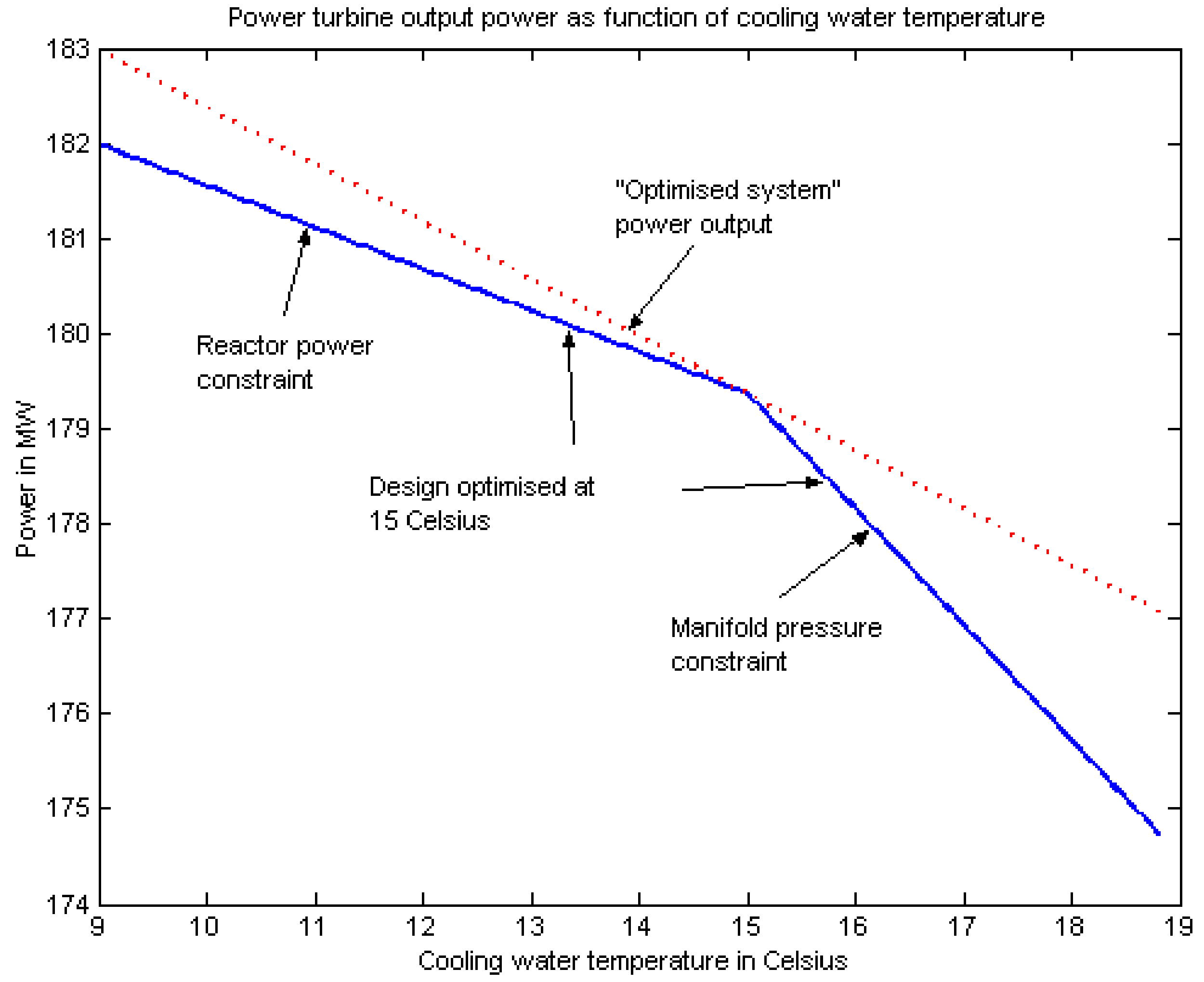
OVERVIEW

- **MHSS is a standard open circuit pumping and piping system similar to a circulating water system in a steam cycle plant.**
- **The system circulates sea water to the PBMR Cooling Water Plant Room, and back to the sea.**
- **Waste heat transfer via plate heat exchangers in the Cooling Water Plant Room, adjacent to the Reactor Building.**
- **The function of the MHSS is to remove waste heat from the following cooling circuits:**
  - The Active Cooling System, consisting of the:
    - *Pre-cooler Cooling Circuit*
    - *Intercooler Cooling Circuit*
    - *Auxiliary Cooling Circuit*
  - The Equipment Protection Cooling Circuit which cools the:
    - *RCCS active mode*
    - *CCS*
    - *CBCS*

MHSS Design Features

- The MHSS transfers 240 MW to the sea based on a sea water outlet temperature of 39.5°C and 15°C inlet temperature.
- The MHSS pumps filtered water from the sea to the CW plant room to the ACS and EPCC heat exchangers.
- The 4 x 50% MHSS pumps are installed in the existing KNPS service water pump house.
- The MHSS pumps have no back-up sea water supply, and loss of this supply will result in a module trip with continued forced cooling via CCS and EPCC.
- The pumps are grouped into two sets of two pumps each, each set being supplied from an independent electrical board.

Power vs. CW Temperature



Active Cooling System (ACS)

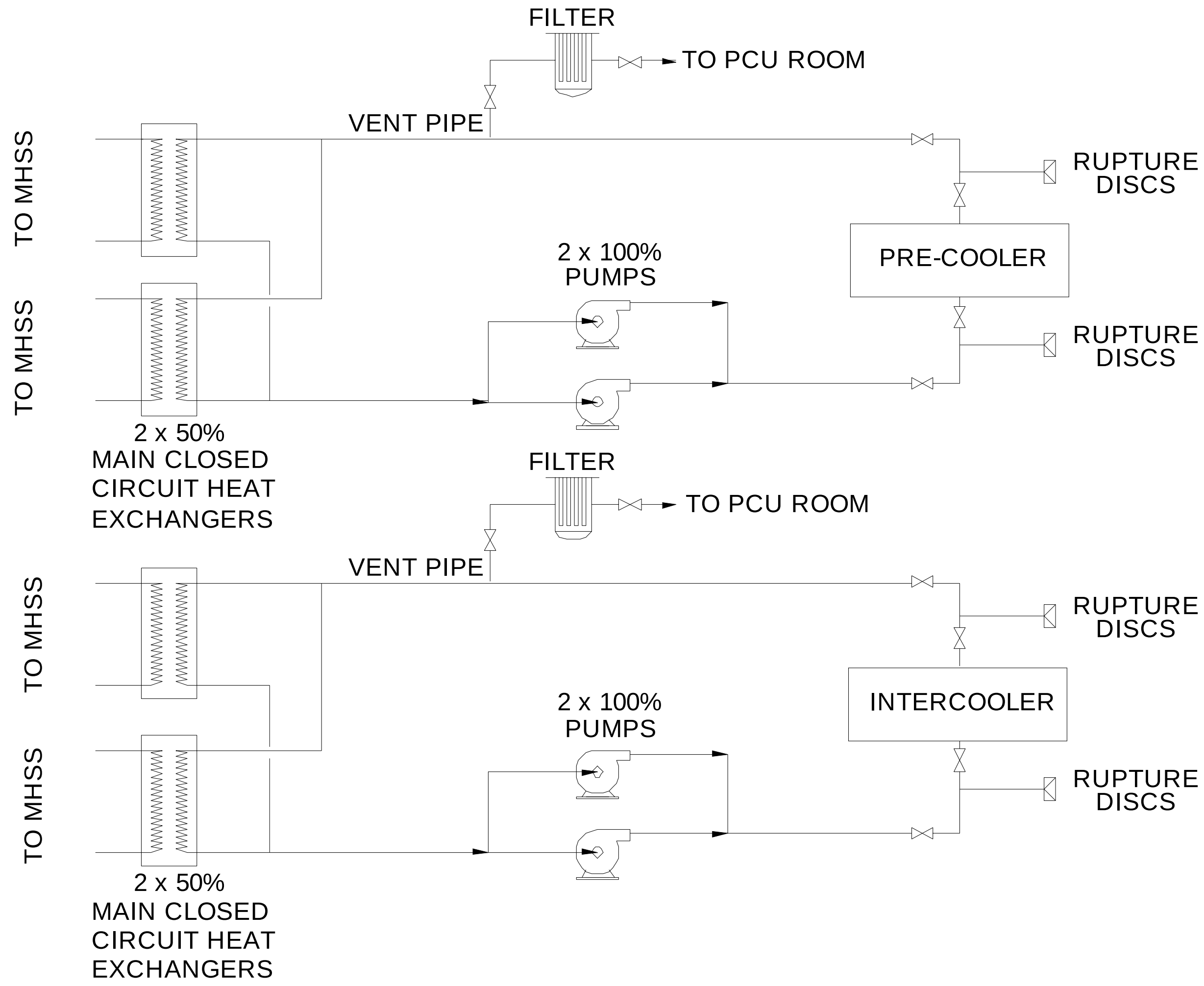
OVERVIEW

- The Active Cooling System (ACS) consists of a number of independent closed circuits that are filled with inhibited demineralized water to prevent the formation of scale and sludge in the inter-cooler and pre-cooler.
- The closed circuits transfer their heat via plate type water-to-water heat exchangers to the sea via the Main Heat Sink System (MHSS).
- The closed circuit cooling systems feature a dedicated water make-up system, which is interconnected with a chemical dosing system that allows monitoring of the inhibitor concentration of the demineralized water.

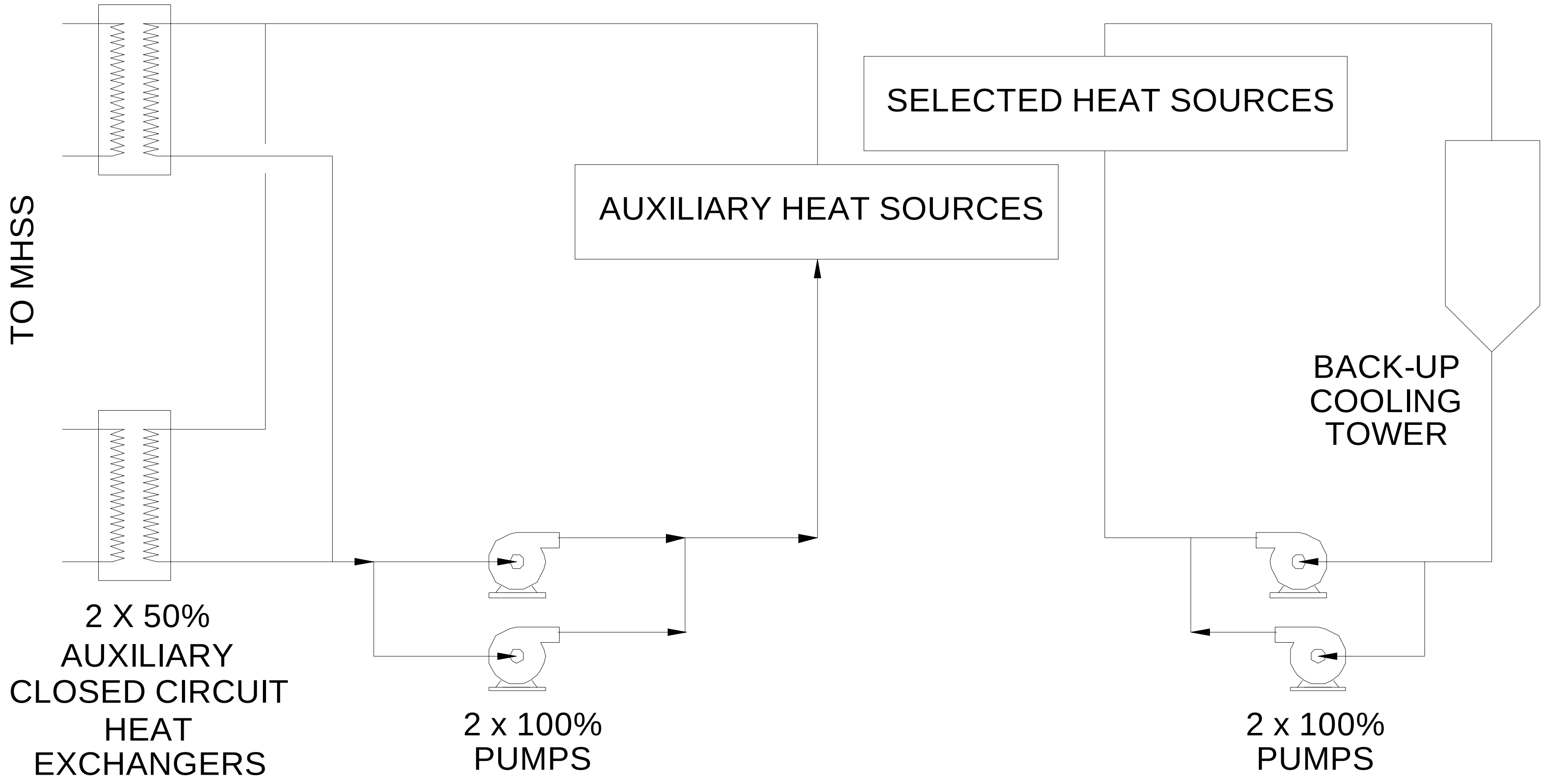
ACS Design Features

- **The ACS comprises three circuits:**
  - Independent Pre-cooler and Intercooler Cooling Circuits (PCC and ICC) transfer approximately 126 MW and 91 MW respectively to the MHSS.
  - Control valves and rupture discs protect against high pressure gas leaks in Pre-cooler or Intercooler and limit water ingress to the Main Power System.
  - The Auxiliary Closed Circuit removes a total of approximately 11.6 MW of waste heat from the following auxiliary systems:
    - *Compressed Air System (CAS)*
    - *Dry Gas Seal Supply and Return System (DSRS)*
    - *Fuel Handling and Storage System (FHSS)*
    - *Generator air coolers*
    - *Heating, Ventilation and Air-conditioning (HVAC) system*
    - *Helium Purification System (HPS)*
    - *Helium Inventory Control System (HICS)*
    - *Primary Loop Initial Clean-up System (PLICS)*
    - *Static Frequency Converter (SFC)*
- **A cooling tower is provided to act as back-up for selected auxiliary systems used following a unit trip (**shown above in red**).**

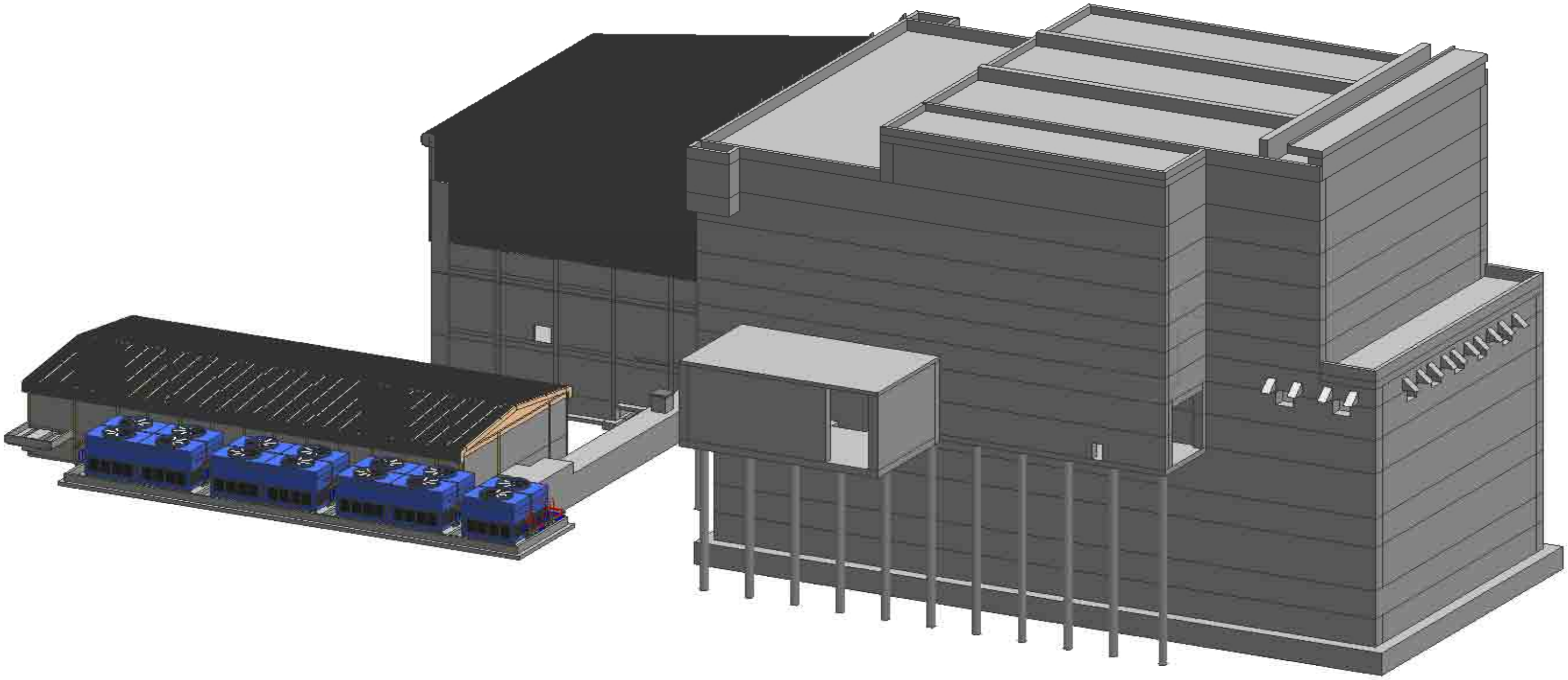
ACS Pre-cooler and Intercooler Circuits



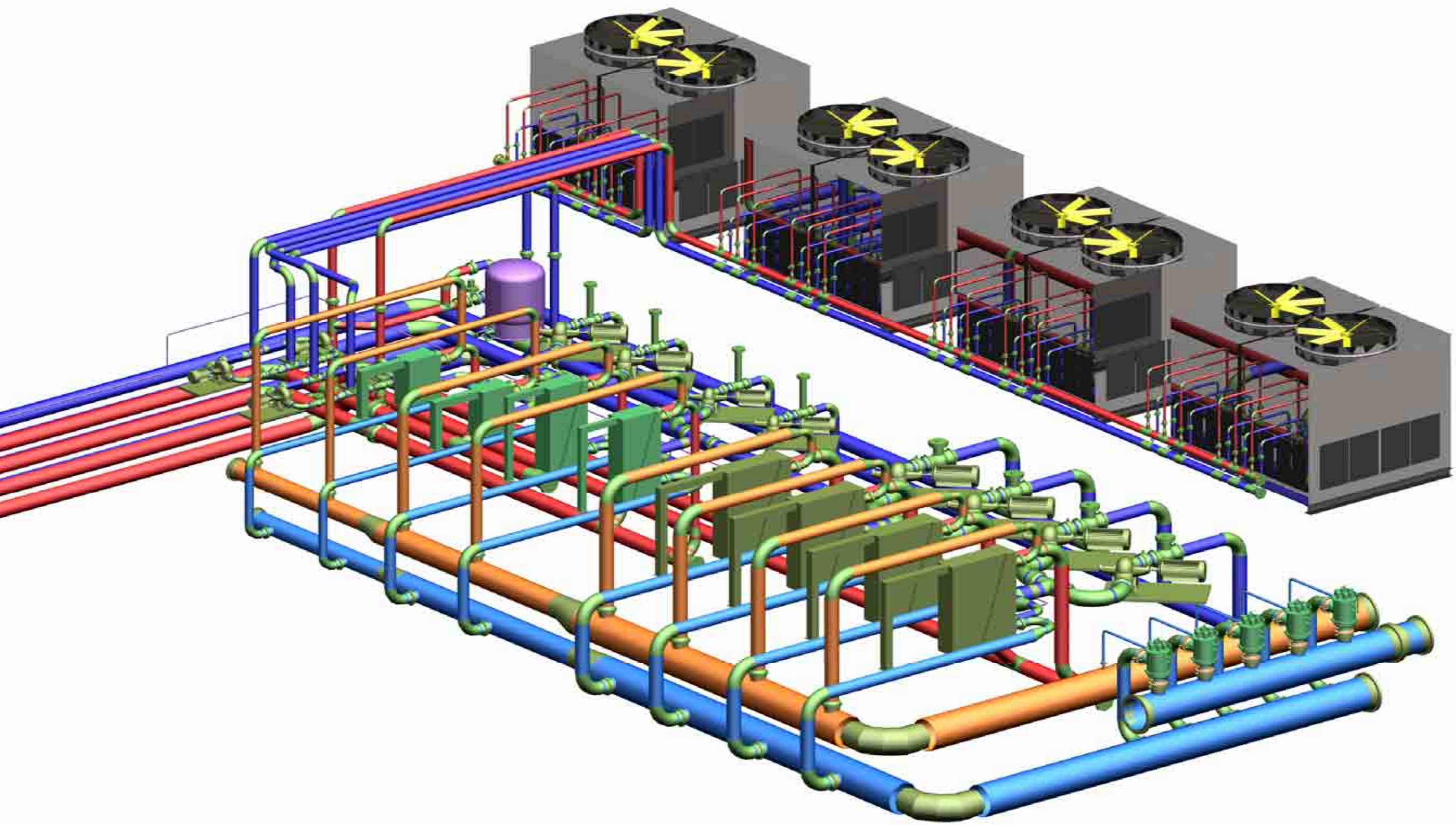
ACS Auxiliary Circuit



PBMR Site Layout with CW Plant Room & Cooling Tower Position



ACS and EPCC Layout in CW Plant Room



RCCS Functions

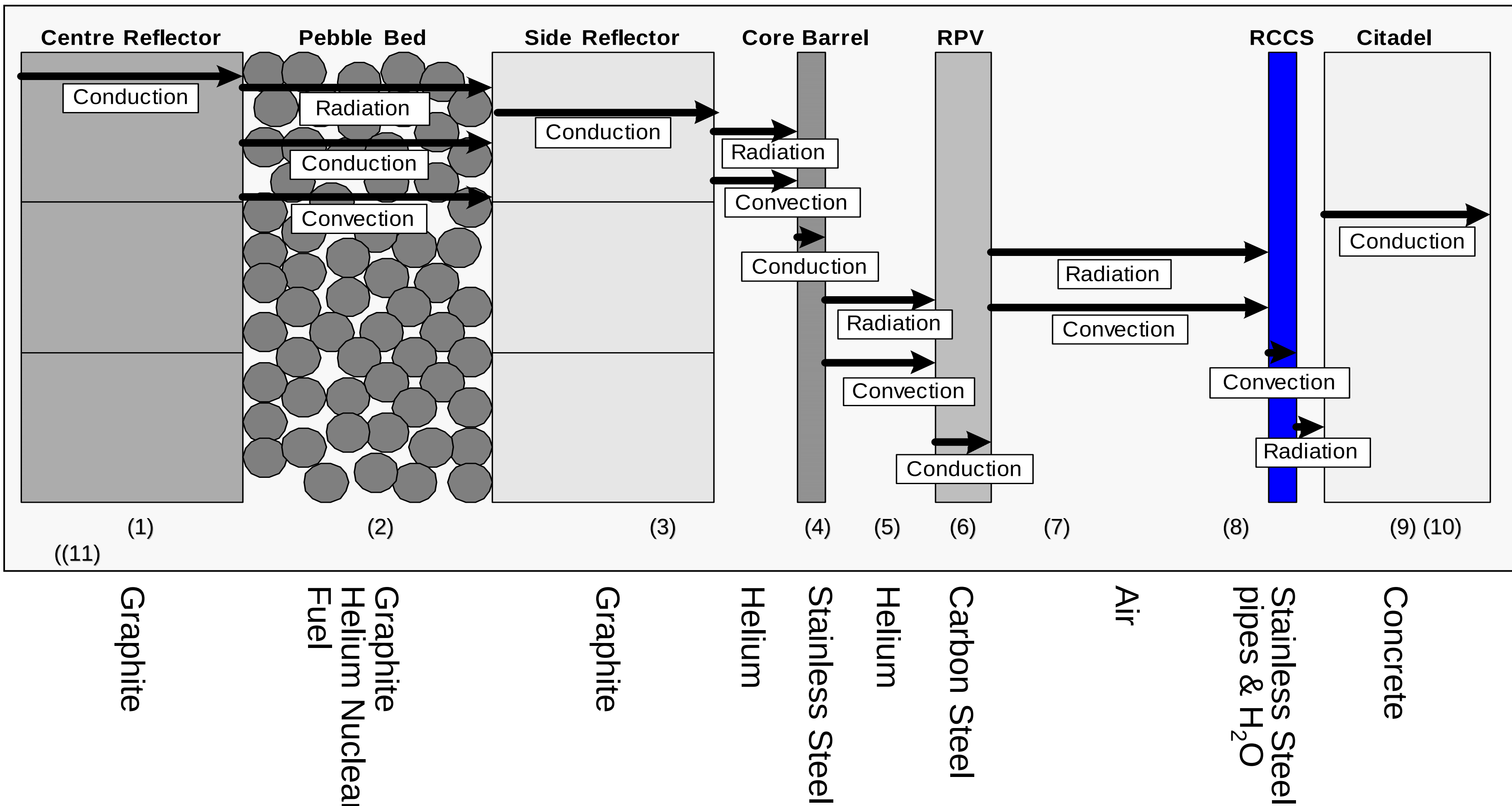
OVERVIEW

- **The Reactor Cavity Cooling System (RCCS):**
  - Removes thermal radiation from the reactor vessel and protects the concrete walls of the reactor cavity.
  - Operates continuously in an active cooling mode during normal plant operation.
  - Removes all decay and residual heat transferred from the core to the reactor cavity during pressurized or depressurized loss of forced cooling events.
  - Operates in the event of the loss of active pumping capacity of the EPCC, to remove heat from the reactor cavity passively, and to release this heat to atmosphere in the form of steam.
  - Is capable of switching from active to passive operation without any mechanical, electrical or human intervention.
- **The RCCS active or passive operability is not required to protect fuel integrity during pressurized and depressurized loss of forced cooling**

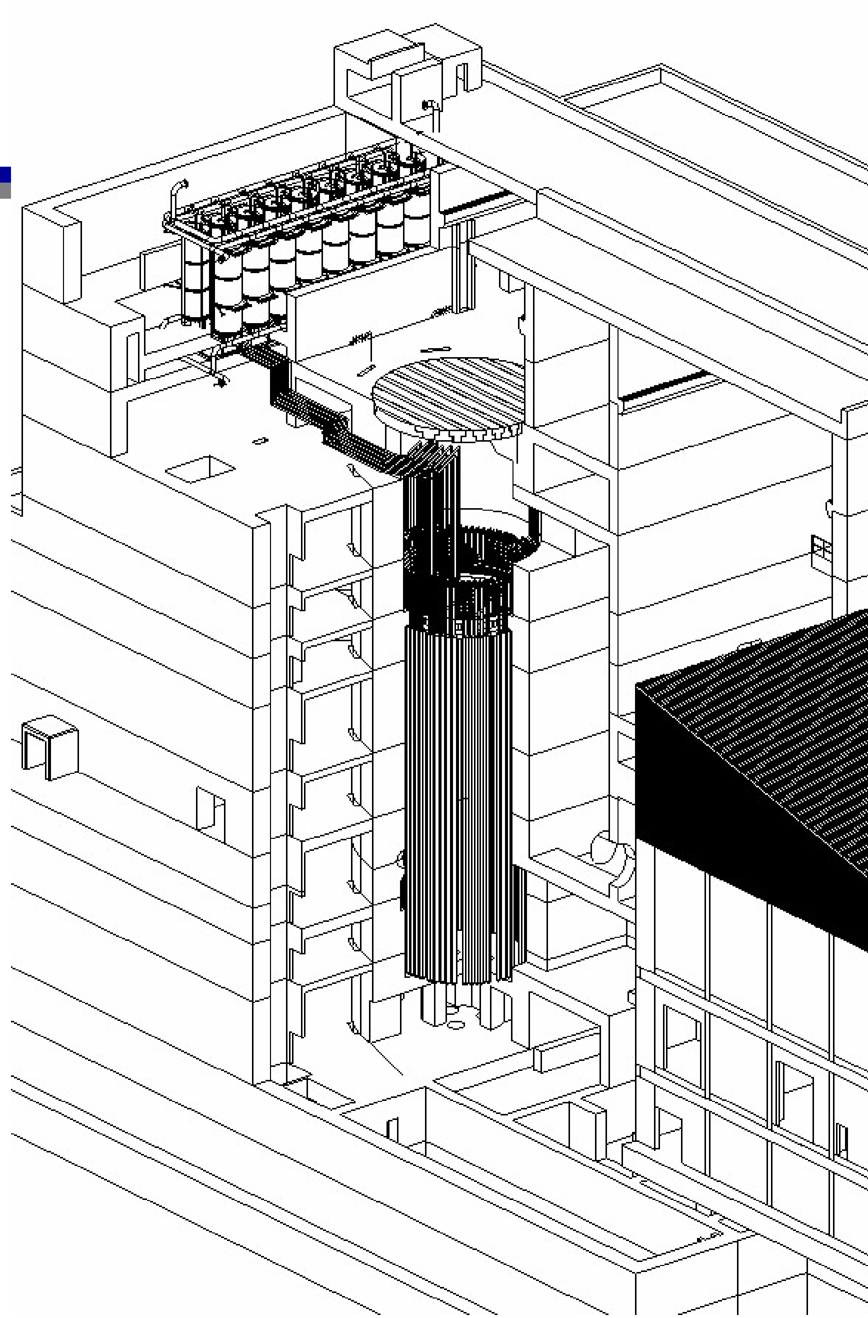
RCCS Design Features

- **Two diverse heat transport paths are provided in the EPCC to support active RCCS cooling mode**
  - Heat transport to the MHSS via 2x100% pumps
  - Heat transport to the EPCC Backup Cooling Tower via 2x100%pumps
  - Each train supported by offsite and on-site AC supplies and standby diesel generators
- **The EPCC has a redundant 100% capacity heat exchanger.**
- **Multiple independent and diverse sources of water to support long term passive RCCS cooling**
  - The RCCS water storage tank inventory
  - Tank resupply via Demineralized Water System
  - Tank resupply via two connections to the Fire Protection System (FPS) with both diesel and motor driven FPS pumps
  - Tank resupply via two external tanker truck connections can be filled from five independent points (four FPSs, one DWS)
- **Full RCCS heat removal capacity is available with one tank and its connected four standpipes out of action.**

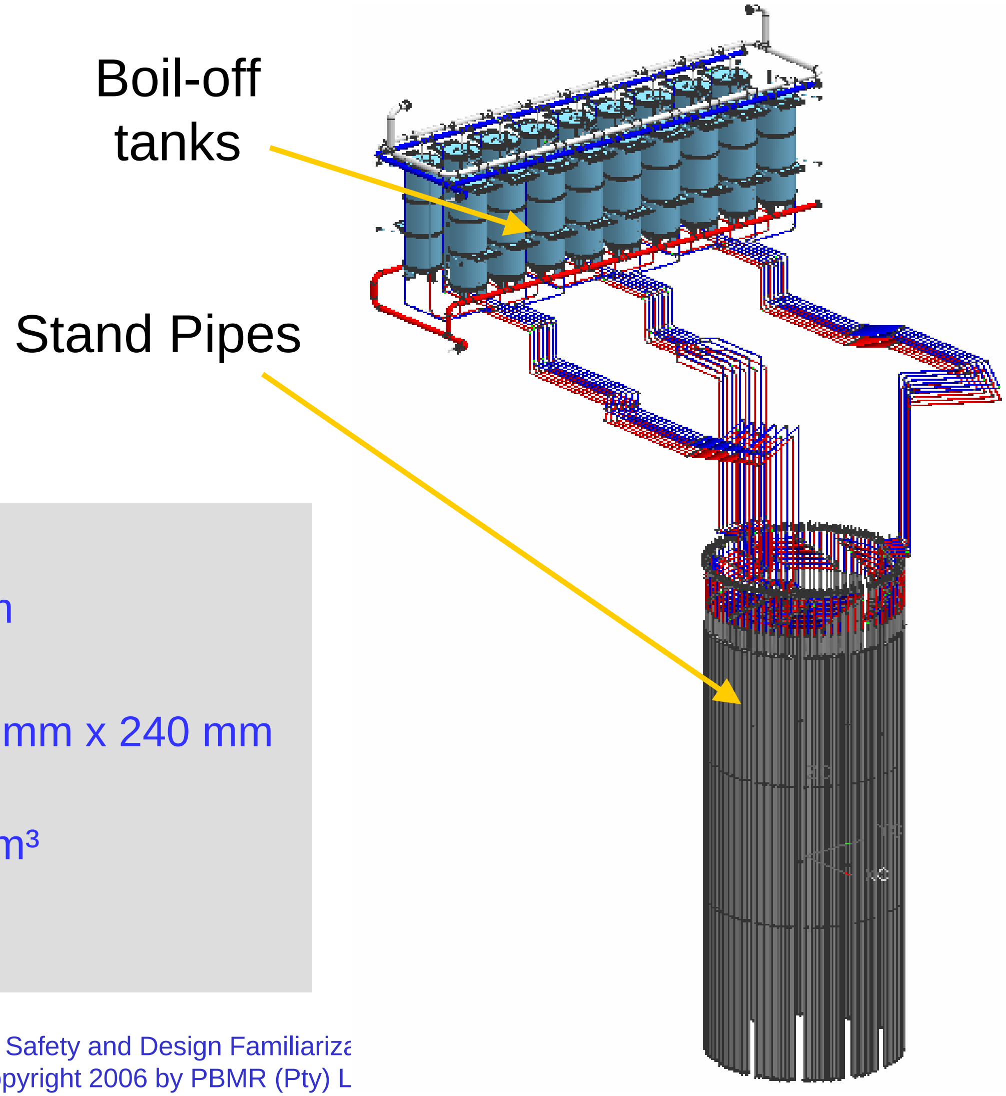
PBMR Passive Heat Removal



RCCS Layout



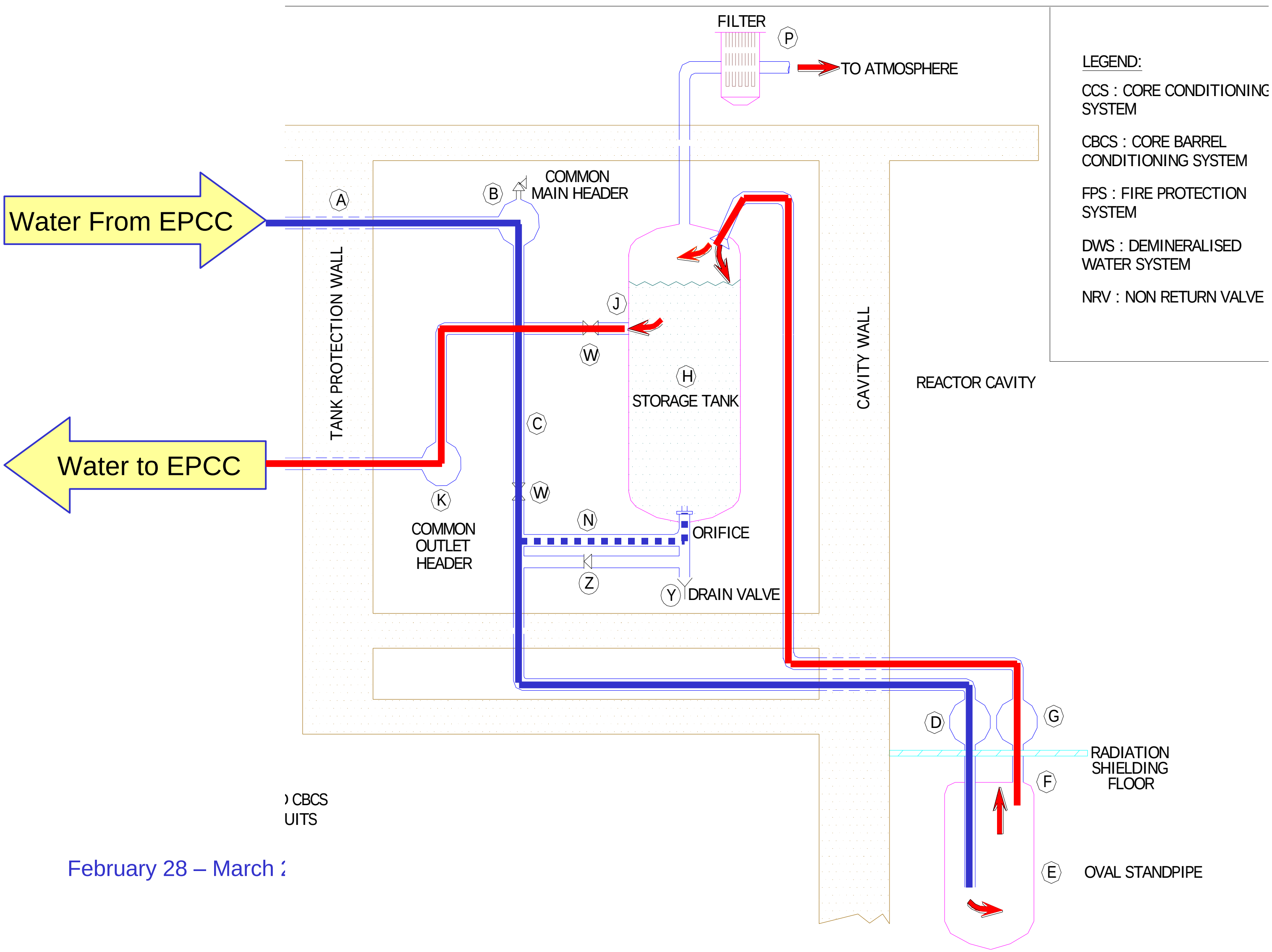
RCCS Stand Pipes



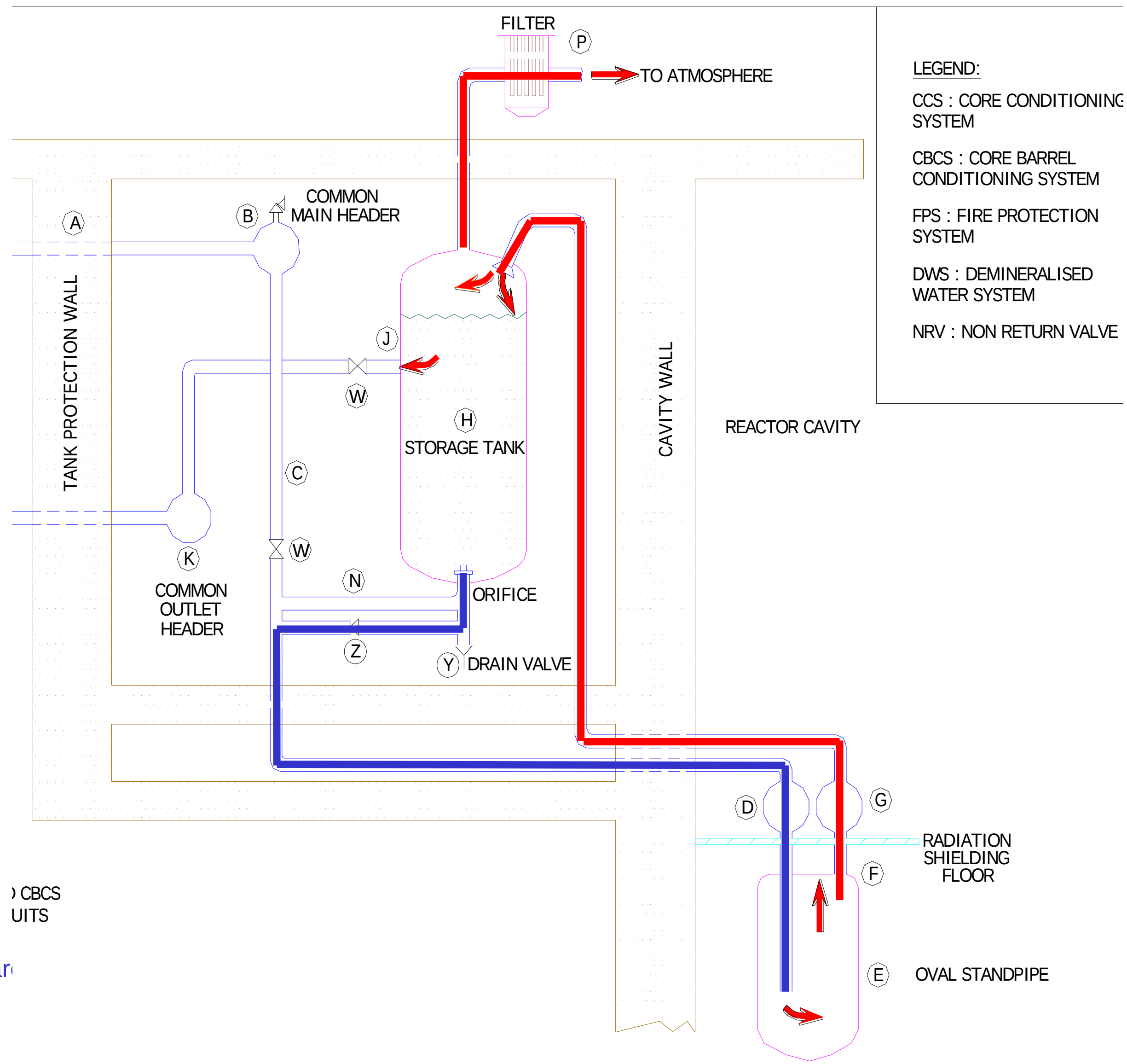
SPECIFICATION

Cooling Pipe length	30 m
Number of cooling pipes	72
Cooling pipe size (oval shape)	500 mm x 240 mm
Boil-off tank capacity	240m³
Number of boil-off tanks	18

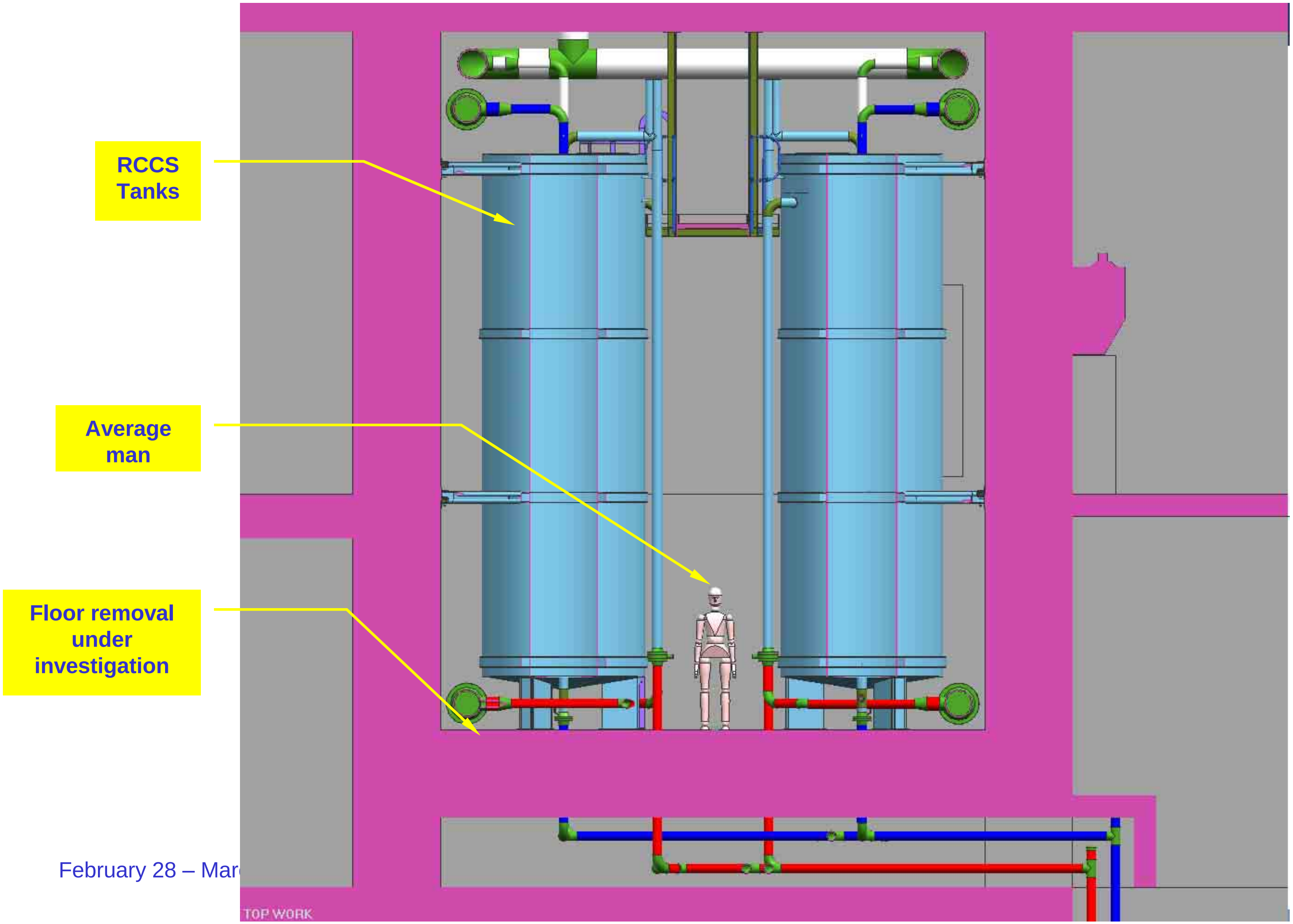
RCCS – Active mode



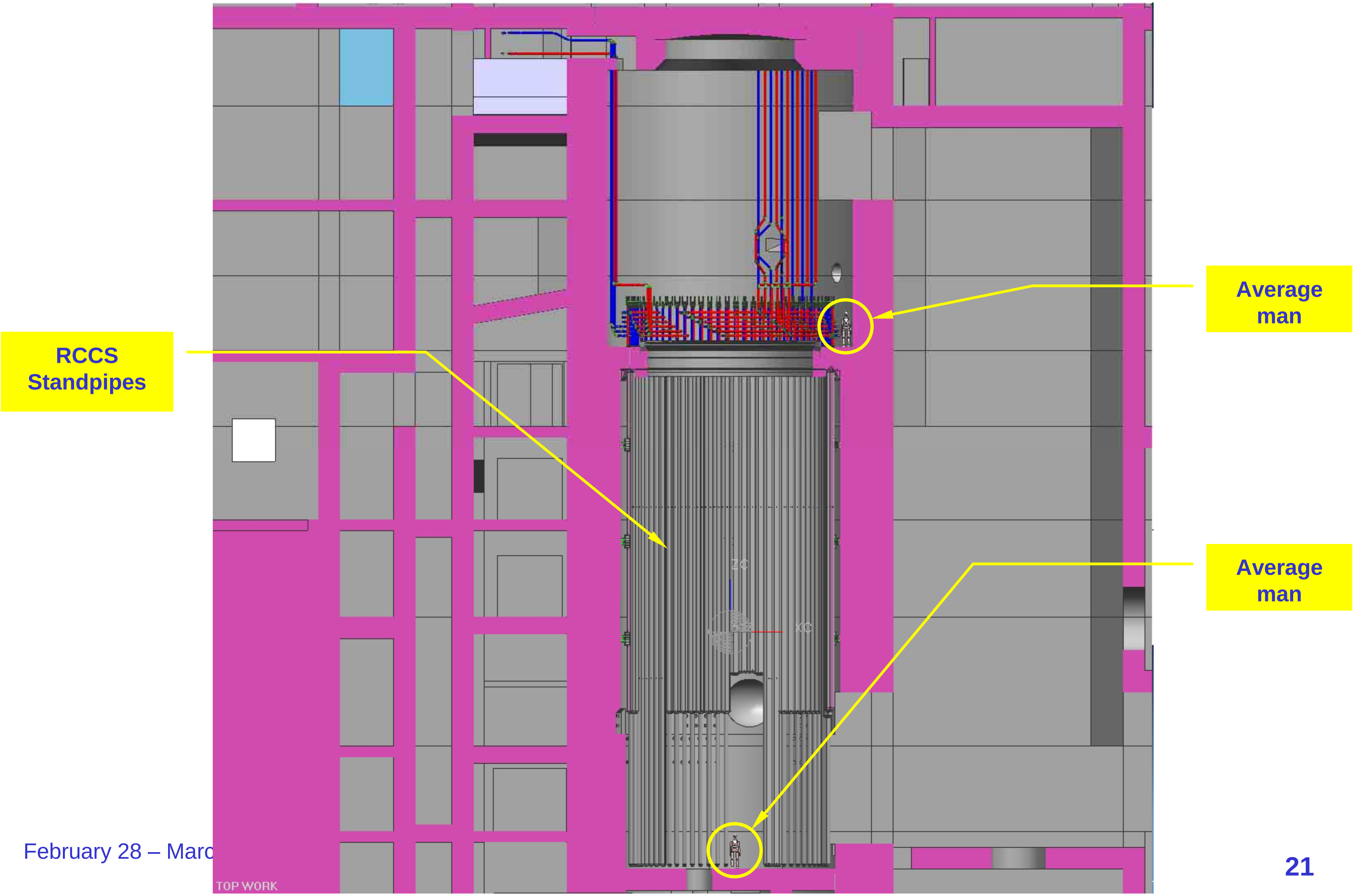
RCCS – Passive mode



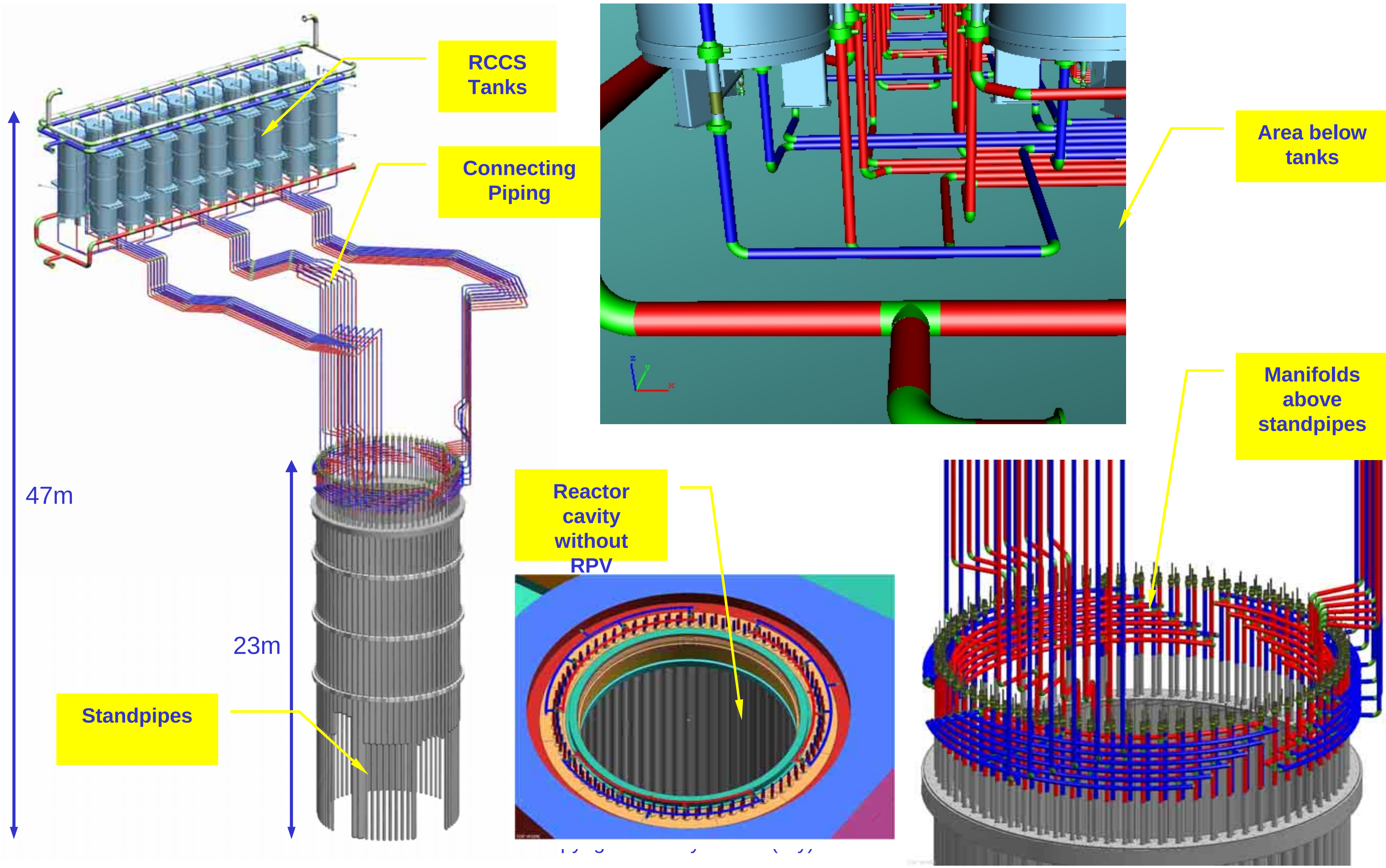
RCCS Layout 1



RCCS Layout 2



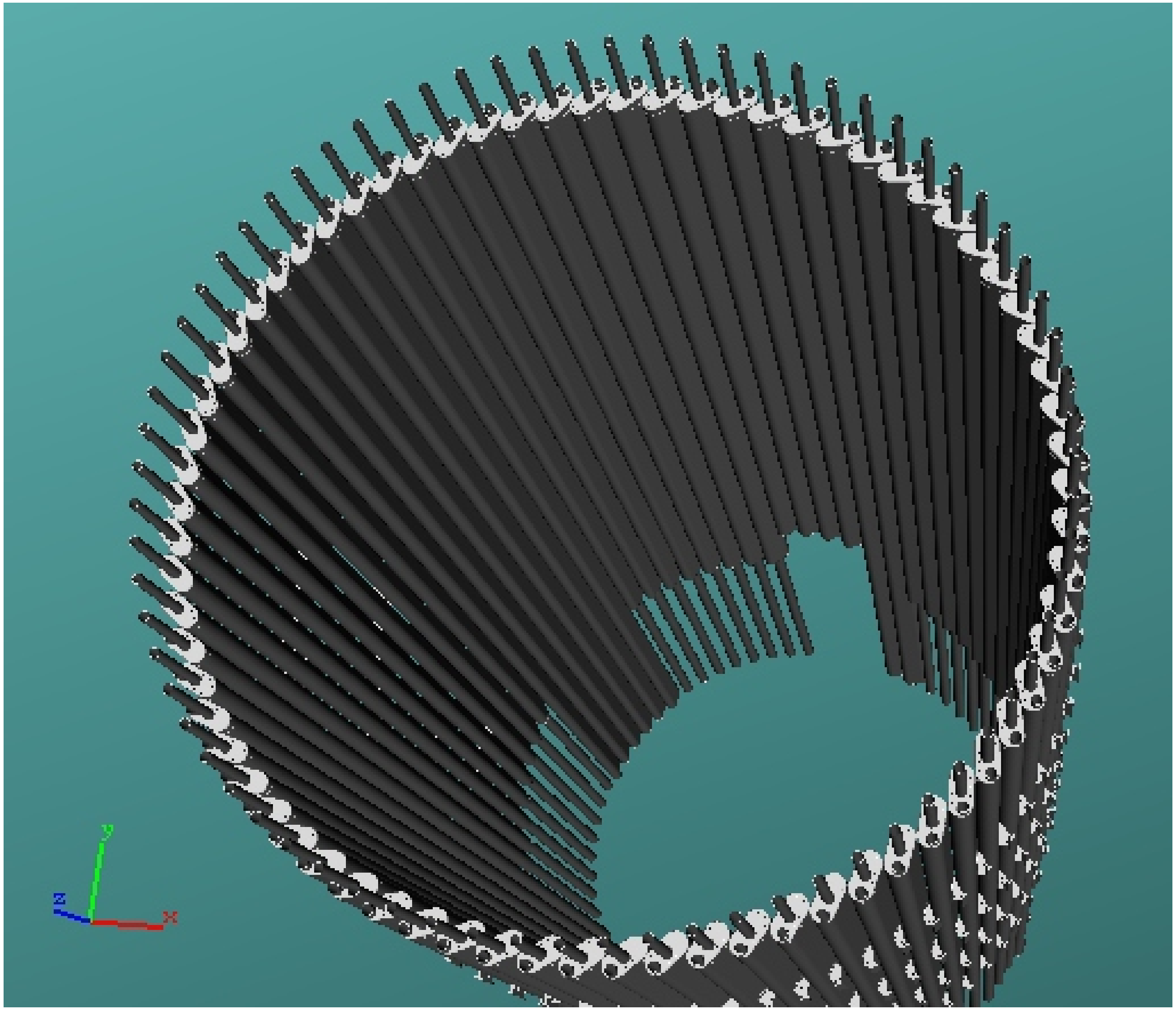
RCCS Layout 3



RCCS Standpipes

- Each standpipe is oval-shaped (500mm x 240mm) to create effective water wall of constant thickness and overlapping to prevent direct shine of thermal radiation on concrete.
- 18 independent circuits each with 1 tank and 4 standpipes
- Active mode success criterion is 17/18 circuits or 68/72 standpipes.
- Engineered to avoid interference with Rx vessel supports
- Operated in active mode at constant flow from EPCC during all modes with fuel in reactor vessel

RCCS Water Curtain Arrangement



Equipment Protection Cooling Circuit (EPCC)

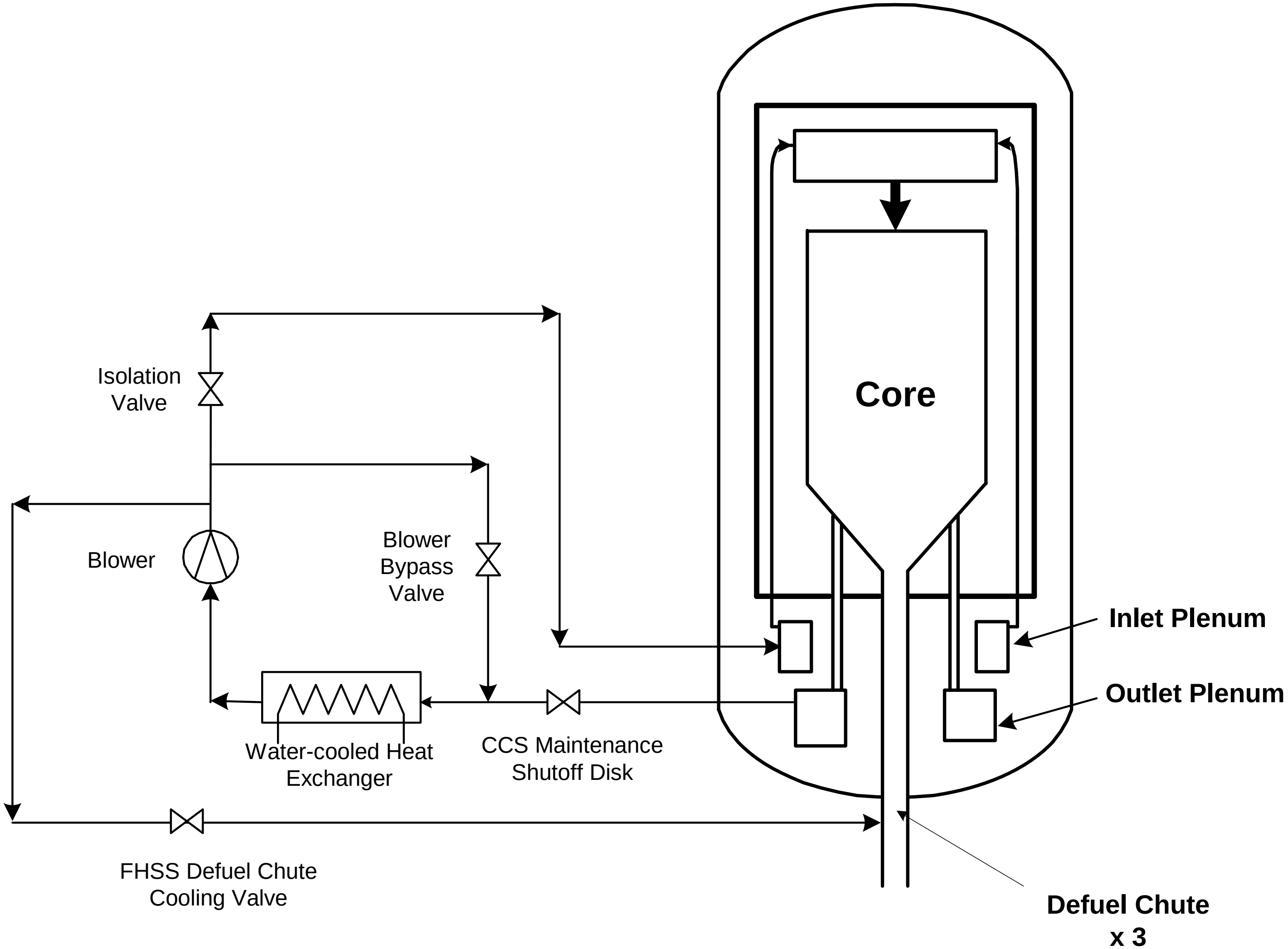
OVERVIEW

- **The closed circuits of the Equipment Protection Cooling Circuit (EPCC):**
  - Are filled with inhibited demineralized water to prevent the formation of scale and sludge in the heat exchangers;
  - Transfer their heat via plate type water-to-water heat exchangers, to the sea via the MHSS.
- **The EPCC provides cooling to:**
  - The Reactor Cavity Cooling System (RCCS)
  - The Core Conditioning System (CCS)
  - The Core Barrel Conditioning System (CBCS)
- **Because active contaminants could make their way into the EPCC via the pipe work and heat exchangers of the RCCS, CCS or CBCS, the EPCC plant room is a controlled area.**

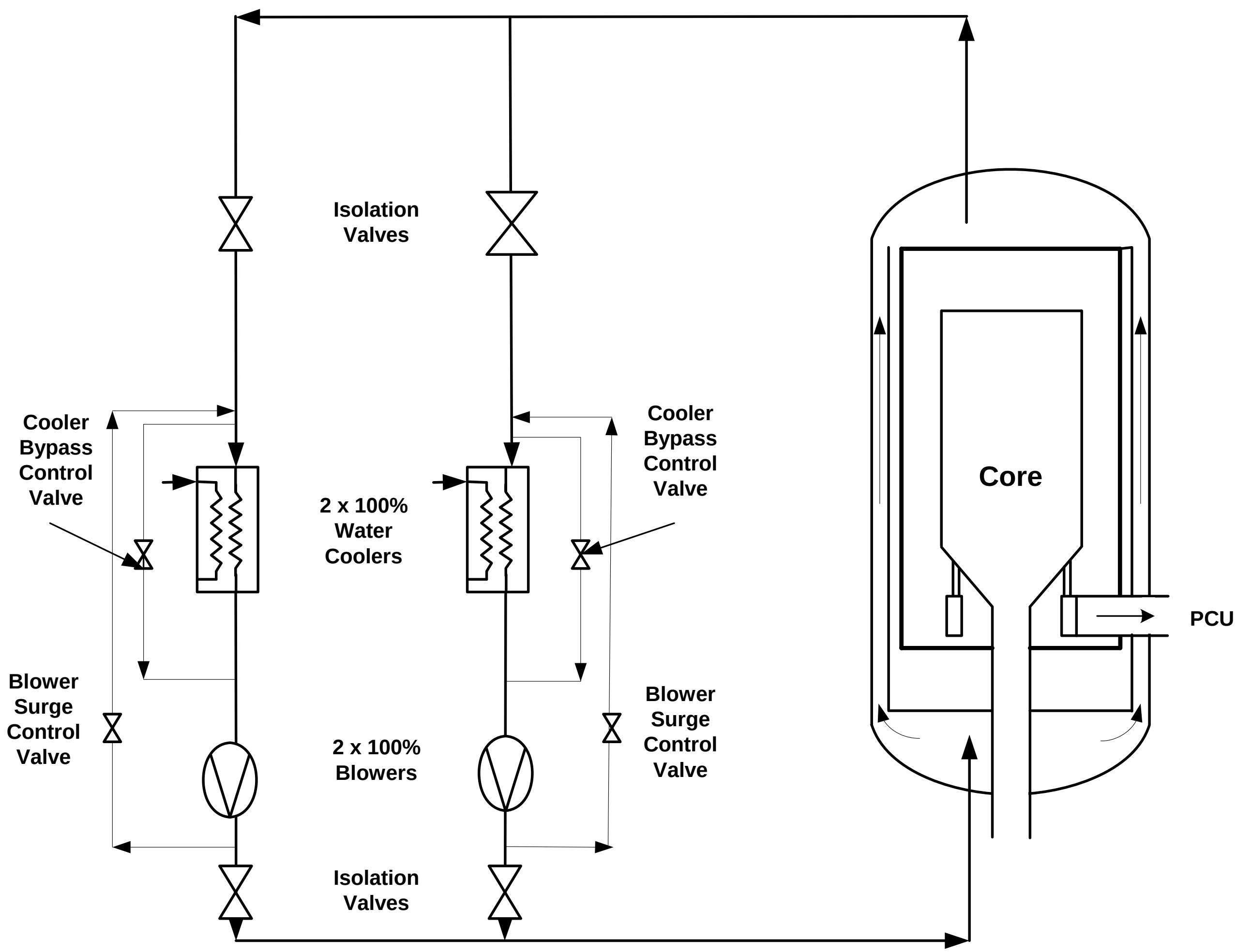
EPCC Design Features and Functions

- **EPCC Main Circuit**
  - Provides cooling for RCCS active mode
  - Provides cooling for CCS and CBCS Buffer Circuits
  - Backed up by EPCC Cooling Tower Circuit
  - Electric power by KNPS ESW power which is backed up by KNPS DGs
- **EPCC Cooling Tower Circuit has electric power backed up by DGs.**
- **CCS and CBCS Buffer Circuits provide water cooling to gas/water Hx in CCS and CBCS.**

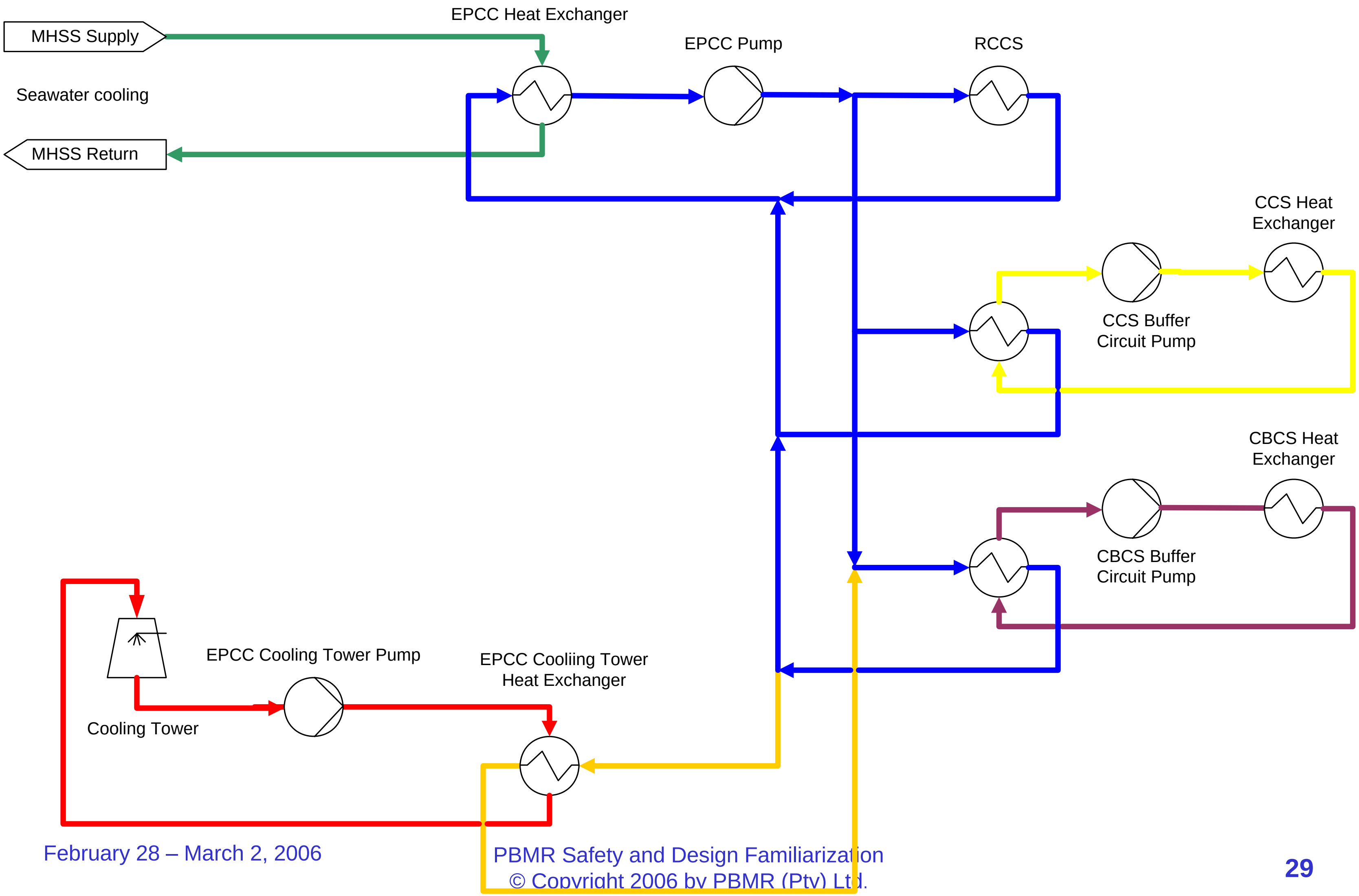
CCS Process Flow



CBCS Process Flow



EPCC Process Flow Diagram



Pressure Relief System (PRS)

- **The prime functions of the PRS are to:**
  - Preserve the structural integrity of the Reactor Building during an emergency depressurization event (defined as a break in the Pressure Boundary (PB) equivalent to a double-ended guillotine break of a pipe with inside diameter up to 230mm)
  - Preserve the structural integrity of the Reactor Cavity (RC) during faulted depressurization events from pipe breaks >230mm
  - Limit delayed release of helium to atmosphere subsequent to any depressurization event
- **Functions are accomplished via rupture panels and ducts between reactor building compartments and relief vents.**

PRS Major Components

- **Major components which form an integral part of the building structural design:**
  - FHSS shaft
  - RPV depressurization openings and shielding floor
  - Lay-down floor
  - Depressurization vent ducts and shaft
  - Discharge vent openings
- **The major components specific to the PRS:**
  - Rupture Panels (PRS-RP). The rupture panels are of the vacuum service type, which are pre-bulged to offer unidirectional operation.
  - Primary Post-Depressurization Damper (PRS-PPDD). The primary post-event closing damper passively closes upon completion of venting.
  - Secondary Post-Depressurization Damper (PRS-SPDD). The secondary post-event closing damper is closed manually as a backup to PRS-PPDD.
  - Missile Barrier (PRS-MB). The missile barriers are custom designed.
  - Dust Seal (PRS-DS). The dust seal prevents dust and dirt from entering the depressurization shaft during normal operating conditions.

PRS Operational Modes

A. **Normal operating conditions; PRS in Standby with components being monitored**

B. **Response to small HPB pipe break (< 10mm)**
   - abnormal operating condition
   - Helium is vented via PRS Route B for small pipe breaks to the PCU area.
   - Ventilation capacity of the HVAC system (1.2 m^3/s) is sufficient to ensure filtered release.

C. **Response to a medium pipe break (< 230mm)**
   - emergency condition
   - Helium is vented to atmosphere via PRS Route C for medium pipe breaks.
   - The route is closed by means of the Post Pressure Relief Damper (PPRDMP) upon completion of depressurization.

D. **Response to a large pipe break (> 230mm)**
   - faulted condition;
   - Helium is vented to atmosphere via PRS Route D for large pipe breaks.
   - The route is closed by means of the PPRDMP upon completion of depressurization.
   - more rupture panels open than Mode C

E. **During Inspection and Testing conditions; PRS system also under inspection and test to confirm/ensure availability and dependability.**

HVAC Functions 1

- **To supply fresh air to the building**
- **To maintain**
  - specified environmental parameters, temperature and where required, humidity
  - sub-atmospheric pressure and direction of flow in the zones
- **To remove**
  - heat from mechanical and electrical equipment
  - airborne radioactive gases, aerosols and dust particles from within the Reactor Building by purging, filtering, recirculation and local extract air. This includes Ar-41 removal from the reactor cavity.

HVAC Functions 2

- To filter Zone 3 areas at the room to limit contamination of ducting
- Minimize environmental impact by filtering Zone 3 exhaust air
- Provide a post event clean-out system
- Close off the HVAC inlet and exhaust points for pipe breaks > 10 mm
- To extract smoke after a fire has been extinguished

HVAC Zones

Static Pressure Zone 3:

- Contains high-energy vessels with potential airborne contamination due to leakage of radioactive gases and particles.
- Contains rooms with high nuclear radiation and forms part of the controlled radiation zone.
- Controlled at 100 Pa (nominal) below atmospheric pressure.
- Filtered exhaust at roof top level (HEPA and active Carbon).

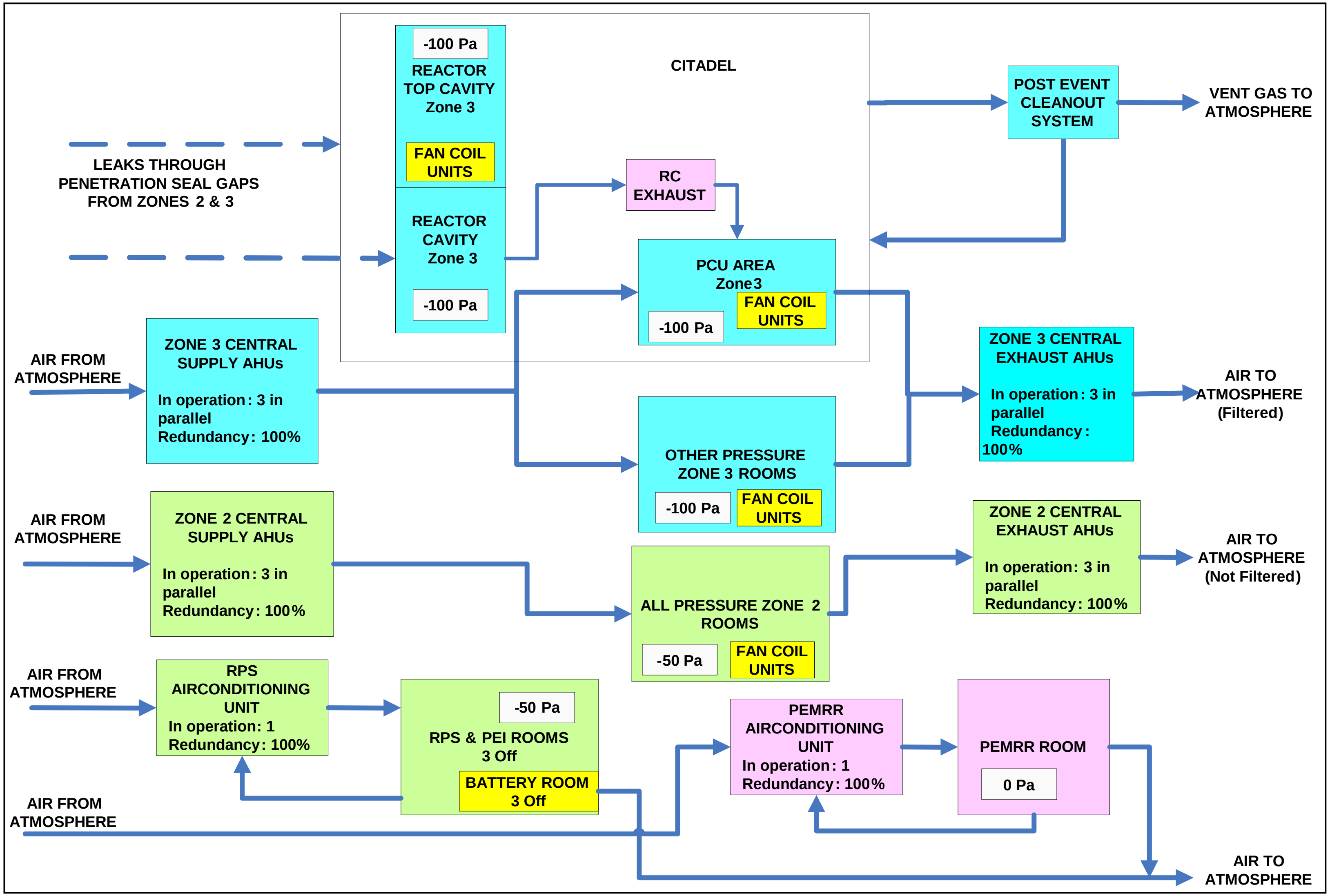
Static Pressure Zone 2:

- Contain rooms with low nuclear radiation exposure.
- Controlled at 50 Pa (nominal) below atmospheric pressure.
- Unfiltered exhaust at roof top level unfiltered.

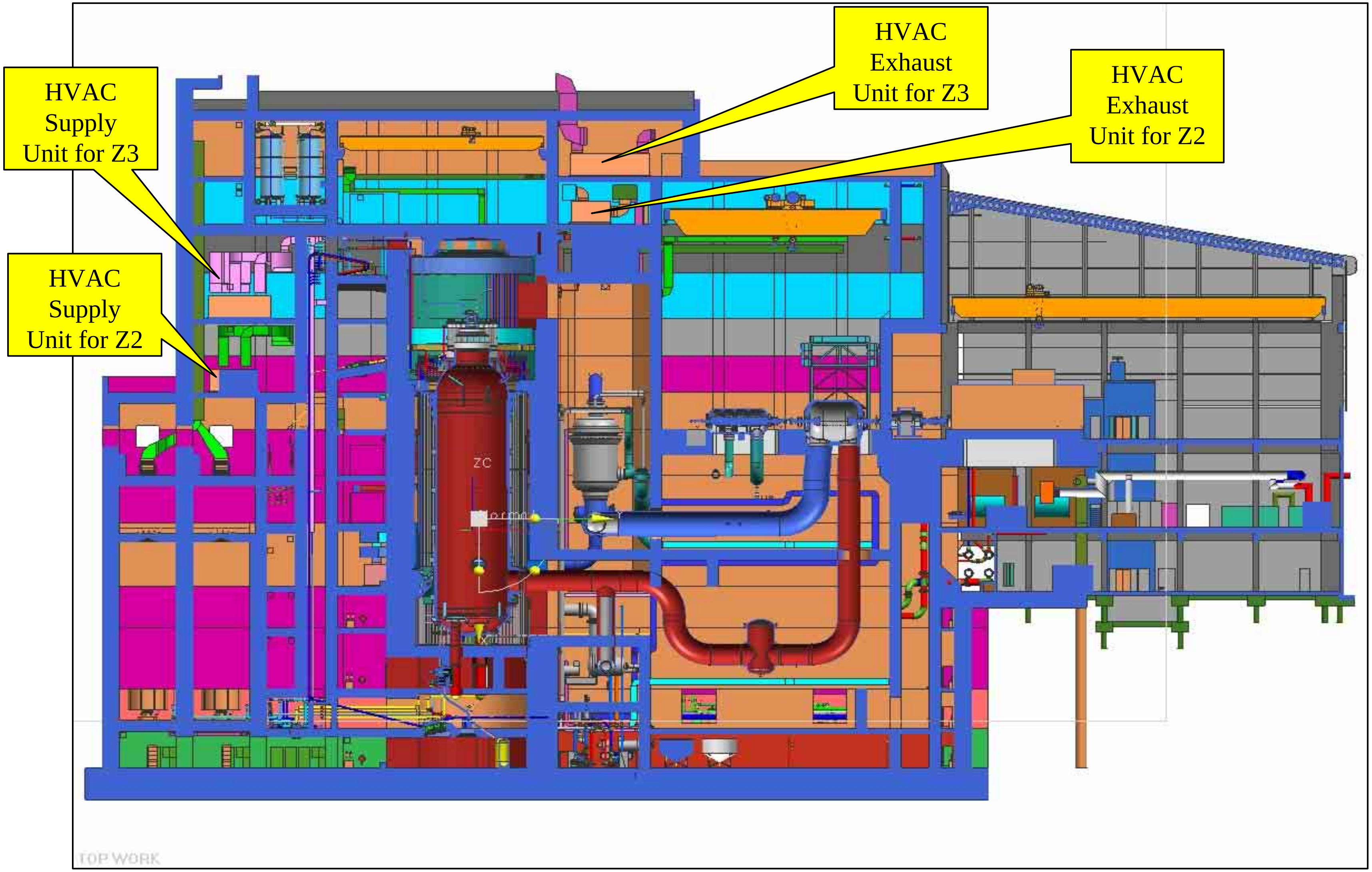
Static Pressure Zone 1:

- Accessible during normal operation and exhaust air will be unfiltered and be classified as Uncontrolled or Supervised Zones.
- Controlled at atmospheric pressure or slightly above.

Heating, Ventilation, and Air Conditioning



Heating, Ventilation, and Air Conditioning



FPS Functions

The Fire Protection System (FPS) provides the following functions:

- Detect and locate fires; provide operator indications
- Extinguish fires in any plant area, protect site personnel, limit fire damage, and enhance safe shutdown capabilities
- Supply fire suppression water at a flow rate and pressure sufficient for automatic sprinkler system plus supplementary fire hose streams, for a minimum of two hours
- Maintain 100% of fire pump design capacity, assuming failure of the largest fire pump or loss of off-site power
- Following an SSE, provide water to hose stations for manual fire fighting within the Nuclear Island
- Serve as one backup water source of water lost due to evaporation from the Reactor Cavity Cooling System (RCCS) when the RCCS is in the passive operational mode

FPS Main Components 1

Common Services

- 2 x 100% Reservoirs
- 2 x 50% Electrical Pumps
- One 100% Diesel Back-up System
- 1 x Jockey Pump
- Fire water reticulation (external)
- Fire Detection System/s

FPS Main Components 2

Reactor Building

- Seismically qualified risers with Hydrants
- Gas Suppression Systems for RPS & Electrical Switchgear Rooms
- Water /foam System at PCU Sump & Turbine / Compressor
- Deluge systems for PEMRR generators
- Passive Systems
- Smoke Control

FPS Main Components 3

Generator Building

- Passive Systems
- Gas Suppression Systems
- Water Suppression Systems
- Detection Systems
- Controlled Drainage
- Smoke Control

Other Fire Risk Areas

- Main Control & PEMMR – Special Considerations
- Transformers – Deluge Systems, Passive & Drainage
- Switchgear Rooms – Gas Suppression Systems
- Cable Tunnels – Sprinkler Systems & Drainage
- Solid Waste Handling & Storage

Waste Handling System (WHS)

OVERVIEW

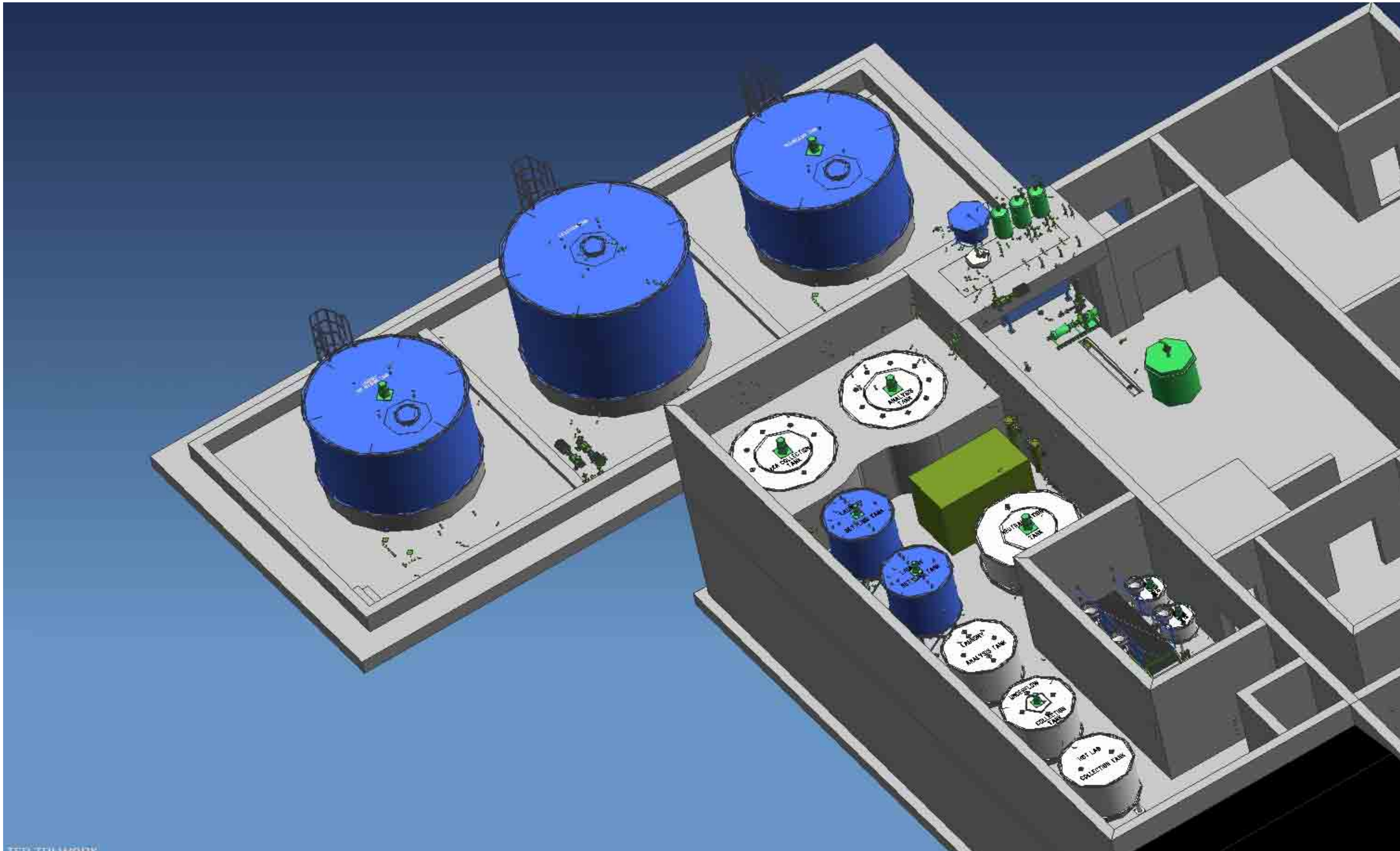
- **The Waste Handling System (WHS) is designed to handle, store and discharge low- and medium-level liquid and solid radioactive waste generated during normal operation, maintenance activities, and upset conditions of the PBMR.**
- **Scope:**
  - **Gaseous Waste**: Due to low levels of radioactivity in process gas streams, no gas waste system is required
  - **Liquid Waste**: Is generated at the hot laundry, hot laboratory, decontamination facility, controlled area washroom, from leaks of the CW circuits inside the Reactor Building, and from general cleaning and fire suppression operations.
  - **Solid Waste**: All radioactive waste from the plant except spent and used fuel, which are part of the FHSS. The solid waste system consists of three subsystems
    - *Compactable waste;*
    - *Non-compactable waste; and*
    - *Waste storage.*

Liquid Effluent Generation

Source	Average Qty (m^3/d)	Max. Qty (m^3/d)	Average Qty (m^3/yr)	Specific Activity (Bq/m^3)
Liquid waste from decontamination and laboratory	1.5	4.5	720	Up to 7.3×10^7
Liquid waste from laundry	1.4	5.6	700	Up to 7.3×10^7
Liquid waste from building drains and sumps	0.4	4.1	365	Up to 7.3×10^6
Liquid waste from showers and washrooms	0.32	0.76	140	Up to 7.3×10^6

P B M R

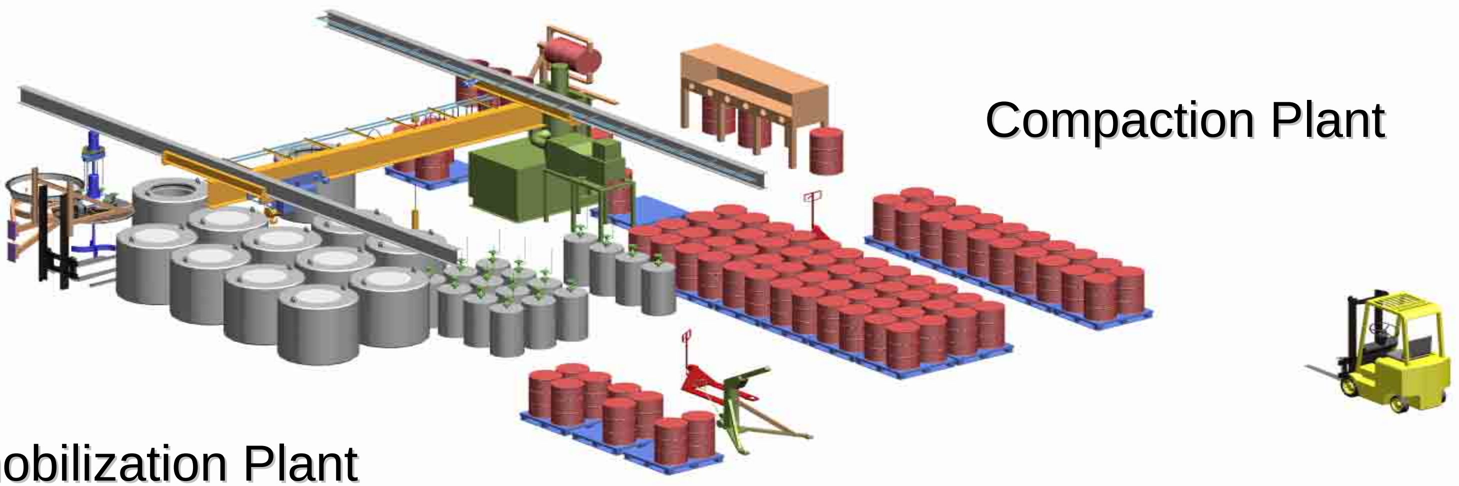
Liquid Waste Handling System



Solid Waste Volume

Waste Type	Source	Volume (Drums/yr)	Expected Activity (Bq/g)
Filters	HVAC Filters (HEPA) Helium filters (sintered SS) Vacuum cleaner filters (cloth and HEPA) FHSS vacuum cleaner filter Dried filters from the liquid waste system	8	0.35
Compactable solid waste	Cloth (paper, overalls, etc.) Sweepings from floors (vacuum cleaner filters)	100	0.35
Non-compactable solid waste	Ion exchanger resins (dried) Gaskets (metal and polymer) Discarded parts (bearings, parts, valve parts, etc.) Electrical motors, heaters elements Bolts, nuts, washers Dust from cyclones, etc.	6	Dependent on the point of origin
Evaporator	Effluent from evaporator (sludge)		1×10^5

Solid Waste – Process Plant



Solid Waste – Storage